Self-Concatenated Codes with Self-Iterative Decoding for Power and Bandwidth Efficiency[1]

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Abstract— **A self-concatenated code with interleavers is a concatenated coded scheme based on only one recursive convolutional code. An upper bound on bit error probability, averaged over all possible interleavers, using maximum-likelihood decoding is obtained. Design rules for the single convolutional code, that maximize the interleavers gain and the effective free distance are presented. Design rules are extended to non-binary modulations for the design of self-concatenated trellis coded modulation. A low-complexity self-iterative decoding algorithm for the self-concatenated code for binary and nonbinary modulation is proposed.**

I. Introduction

The basic concept of self-concatenation scheme [3], motivated by the concept of turbo codes [1], was independently proposed by Loeliger [2] for the special case of one interleaver and binary modulation. A self-concatenated code with $b(q-1)$ interleavers, is a concatenated coded scheme based on one rate bq/n recursive convolutional code, which accepts the b information sequences and their permuted versions through $b(q-1)$ interleavers at its bq inputs. An example for b=1, and q=3 is shown in Fig. 1. As for turbo codes the information data is transmitted only once. The self-concatenated code is best suited for the construction of trellis coded modulation (TCM), based on one trellis.

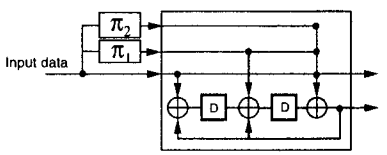

Fig. 1: A rate 1/2, 4-state, self-concatenated code, b=1, q=3.

The maximum likelihood performance of binary self-concatenated codes averaged over all possible interleavers is obtained for b=1 and recursive code as

$$\lim_{N\to\infty} P_b(e) \doteq BN^{-\lfloor \frac{q+1}{2} \rfloor} Q\left(\sqrt{2R_c\, h(\alpha_M)\, E_b/N_0}\right) \qquad (1)$$

where the constant B is independent of N, the input block size, and $h(\alpha_M)$ is equal to $qd_{f,\text{eff}}/2$ for q even, and to $(q-3)d_{f,\text{eff}}/2 + h_m^{(3)}$ for q odd. $d_{f,\text{eff}}$, the effective free distance, and $h_m^{(3)}$ are the minimum weights of output code words due to input sequences of weight 2, and 3 respectively. R_c is the overall code rate. $N^{-\lfloor \frac{q+1}{2} \rfloor}$ represents the interleaving gain.

II. Self-Concatenated TCM

We propose a novel method to design self-concatenated TCM, which achieves b bits/sec/Hz, using a single, rate $bq/(bq+1)$ recursive systematic binary convolutional encoder. Consider b binary streams entering the self-concatenated TCM, and $b(q-1)$ interleavers. Each set of $(q-1)$ interleavers are connected to a distinct input data stream. The b input bits plus one parity which make $b+1$ outputs of the encoder are mapped to $2^{(b+1)}$ modulation signal points. In this way, we are using b information bits for every modulation symbol interval, resulting in b bit/sec/Hz transmission. For illustration, the basic structure of self-concatenated TCM for b=2, q=2, and 8PSK modulation is shown in Fig. 2. This achieves 2 bits per 8PSK symbol time duration. The self-iterative decoder using soft-input soft-output (SISO) APP module [3] and its performance for decoding the self-concatenated TCM in Figure 2 is shown in Fig. 3 where each interleaver is 8192 bits long. In Fig. 3, the received complex samples $\{y_k\}$ at the output of the receiver matched filter are $y_k = Ax(c_k) + n_k$, the complex noise has variance σ^2 per dimension, $x(c_k)$ are complex modulation symbols, and $E\{|x(c_k)|^2\}$=1, which is the assumed channel model $(E_s/N_o = A^2/2\sigma^2)$.

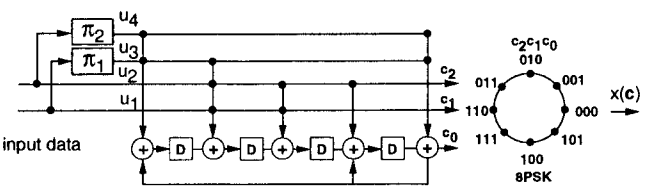

Fig. 2: Encoder for a self-concatenated TCM with 8PSK.

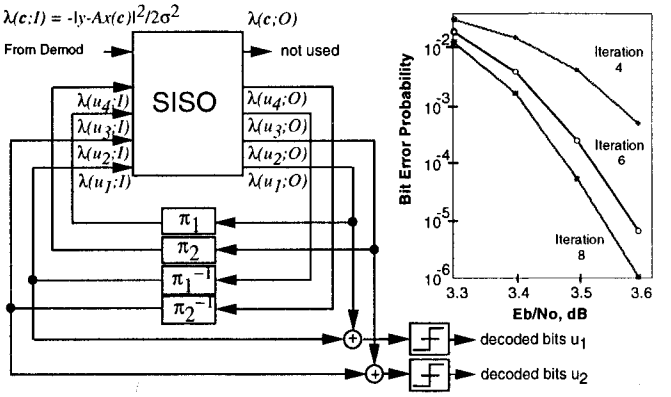

Fig. 3: Self-iterative decoder and simulation results for the Self-Concatenated TCM with 8PSK of Fig. 2

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